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Dietary patterns, insulin sensitivity and inflammation in older adults

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Abstract

Background/Objectives—Several studies have linked dietary patterns to insulin sensitivity and systemic inflammation, which affect risk of multiple chronic diseases. The purpose of this study was to investigate the dietary patterns of a cohort of older adults, and examine relationships of dietary patterns with markers of insulin sensitivity and systemic inflammation.

Subjects/Methods—The Health, Aging and Body Composition (Health ABC) Study is a prospective cohort study of 3075 older adults. In Health ABC, multiple indicators of glucose metabolism and systemic inflammation were assessed. Food intake was estimated with a modified Block food frequency questionnaire (FFQ). In this study, dietary patterns of 1751 participants with complete data were derived by cluster analysis.

Results—Six clusters were identified, including a 'Healthy foods' cluster, characterized by higher intake of lowfat dairy products, fruit, whole grains, poultry, fish and vegetables. In the main analysis, the 'Healthy foods' cluster had significantly lower fasting insulin and HOMA-IR than the 'Breakfast cereal' and 'High-fat dairy products' clusters, and lower fasting glucose than the 'High-fat dairy products' cluster ($P \leq 0.05$). No differences were found in 2-hour glucose. With respect to inflammation, the 'Healthy foods' cluster had lower IL-6 than the 'Sweets and desserts' and 'High-fat dairy products' clusters, and no differences were seen in CRP or TNF-α.

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Conflict of interest The authors declare no conflict of interest.

Conclusions—A dietary pattern high in lowfat dairy products, fruit, whole grains, poultry, fish and vegetables may be associated with greater insulin sensitivity and lower systemic inflammation in older adults.

Keywords

diet; dietary patterns; insulin sensitivity; inflammation; older adults

Introduction

Recent research suggests that older adults' diets can significantly influence their risk of developing adverse metabolic conditions, including insulin resistance and type 2 diabetes (Corpeleijn *et al*., 2006; Ilanne-Parikka *et al*., 2008). Several studies have also linked diet to markers of systemic inflammation, such as C-reactive protein (CRP), an acute-phase reactant, and proinflammatory cytokines interleukin-6 (IL-6) and tumor necrosis factor- α (TNF-α) (Esmaillzadeh *et al*., 2007a). Inflammation has been implicated in the pathogenesis of multiple chronic conditions, including cardiovascular disease and type 2 diabetes, though underlying mechanisms have not been fully elucidated (Guest *et al*., 2008).

One method of assessing the overall dietary influence on metabolic risk is through dietary pattern analysis. Unlike studies that focus on specific nutrients or foods, dietary pattern analysis accounts for the combined effects of individual nutrients and foods. Recent research has associated a "healthy" dietary pattern with lower insulin resistance and systemic inflammation (Esmaillzadeh *et al*., 2007a, 2007b).

Though insulin resistance has been linked to inflammation, and both have been implicated in chronic diseases, few studies have examined dietary patterns in relation to both insulin resistance and inflammation, particularly among older adults. Fewer studies have considered potential genetic influences. The peroxisome proliferator-activated receptor-γ (PPAR-γ) is expressed in adipose tissue and regulates adipocyte differentiation and gene expression. A common polymorphism (Pro12Ala) in the *PPAR-γ2* isoform of the *PPAR-γ* gene has been associated with both insulin sensitivity and inflammation, and its effects may depend on the diet (Memisoglu *et al*., 2003). The objective of this study was to determine whether older adults with different dietary patterns differ in indicators of insulin sensitivity and systemic inflammation, while taking into account a potential genetic interaction.

Research Design and Methods

Study population

Participants aged 70 to 79 were recruited for the Health, Aging and Body Composition (Health ABC) Study, a prospective cohort study, from a random sample of white Medicare-eligible residents and from all age-eligible black residents of selected areas of Pittsburgh, Pennsylvania, and Memphis, Tennessee. Individuals were eligible for the Health ABC study if they planned to remain in the area for at least 3 years and reported no life-threatening cancers and no difficulty with basic activities of daily living, walking ¼ mile or climbing 10 steps. Those who used assistive devices were excluded from the Health ABC study, as were individuals who were already participating in a research study that involved taking

medications or changing their eating or exercise habits. Protocols were approved by institutional review boards at both study sites, and participants provided written, informed consent. An interview on behavior, health status, and social, demographic and economic factors, and a clinical examination of body composition, biochemical variables, weight-related health conditions and physical function were administered between 1997 and 1998, with annual follow-up assessments.

Data from baseline and year 2 of the Health ABC study were used in the current analyses. The sample size for this study was 1751, after excluding participants who did not have a dietary assessment (n = 343); those diagnosed with type 2 diabetes before dietary intake was assessed (n = 548); men who reported an energy intake <800 or >4000 kcal/day and women who reported an intake <500 or >3500 kcal/day (n = 81); and those with incomplete information on outcome or control variables (n = 352).

Dietary assessment

Food intake was measured in year 2 of the Health ABC study with a 108-item food frequency questionnaire (FFQ). This FFQ was designed specifically for the Health ABC study by Block Dietary Data Systems (Berkeley, CA), based on reported intakes of non-Hispanic white and black residents of the Northeast and South over age 65 in the third National Health and Nutrition Examination Survey. The FFQ was administered by a trained dietary interviewer, and interviews were periodically monitored to assure quality and consistency. Wood blocks, real food models, and flash cards were used to help participants estimate portion sizes. Nutrient and food group intakes were determined by Block Dietary Data Systems, as were participants' dietary GI and GL values, as described previously (Sahyoun *et al*., 2005). A Healthy Eating Index (HEI) score, which reflects how well the diet conforms to the recommendations of the Dietary Guidelines for Americans and the Food Guide Pyramid, was also calculated for each participant (Kennedy *et al*., 1995).

In this study, individuals were grouped according to their overall dietary patterns by cluster analysis, based on previous methods (Newby *et al*., 2003). The purpose of the cluster analysis was to place individuals into mutually exclusive groups such that persons in a given cluster had similar diets which differed from those of persons in other clusters. First, the 108 FFQ food items were consolidated into 40 food groups according to similarity in nutrient content (Appendix 1). The percentage of energy contributed by each food group for each participant was calculated and used in the cluster analysis. The reason for this standardization was to account for differences in total energy needs due to gender, age, body size and level of physical activity.

The FASTCLUS procedure in SAS (version 9.1; SAS Institute Inc., Cary, NC) was used to generate dietary pattern clusters. This procedure requires the number of clusters to be specified in advance, and generates mutually exclusive clusters by comparing Euclidean distances between each subject and each cluster center in an interactive process using a K-means method. To determine the most appropriate number of clusters, 2 to 8 cluster solutions were run. Plots of R^2 by the number of clusters and of the ratio of between-cluster variance to within-cluster variance by the number of clusters were examined. A set of 6 clusters was selected, as this solution most clearly identified distinct and nutritionally

meaningful dietary patterns while maintaining a reasonable sample size in each group for subsequent regression analyses. Mean percent energy contributions from food groups were examined according to dietary pattern clusters. Clusters were named according to food groups that on average contributed relatively more to total energy intake.

Measures of glucose metabolism

Fasting glucose and fasting insulin were assessed at baseline of the Health ABC study, from blood drawn through venipuncture after an overnight fast and stored at -70°C. Plasma glucose was measured by an automated glucose oxidase reaction (YSI 2300 Glucose Analyzer; Yellow Springs Instruments, Yellow Springs, OH), and serum insulin with a commercially available radioimmunoassay kit (Pharmacia, Uppsala, Sweden). Homeostasis model assessment of insulin resistance (HOMA-IR), an estimate of insulin resistance derived from fasting glucose and insulin levels, was calculated according to the formula: [fasting insulin (μU/mL) × fasting glucose (mmol/L)/22.5] (Matthews *et al*., 1985). To evaluate glucose tolerance, an oral glucose tolerance test (OGTT) was administered at baseline to participants without diagnosed type 2 diabetes. After blood was drawn for glucose and insulin measurements, participants ingested 75 g of glucose in solution (glucola), and another blood sample was drawn after 2 hours. Biological specimens were processed according to standardized protocols by the Laboratory of Clinical Biochemistry at the University of Vermont (Health ABC, 2008).

Markers of inflammation

CRP, IL-6 and TNF-α were measured in fasting blood samples at baseline of Health ABC. IL-6 and TNF-α levels were measured in duplicate with enzyme-linked immunosorbent assay (ELISA) kits from R&D Systems (Minneapolis, MN). The detectable limit was 0.10 pg/mL for IL-6 (using HS600 Quantikine kit) and 0.18 pg/mL for TNF-α (using HSTA50 kit). Serum CRP levels were also measured in duplicate using ELISA based on purified protein and polyclonal anti-CRP antibodies (Calbiochem, San Diego, CA). The CRP assay was standardized according to the World Health Organization First International Reference Standard, with a sensitivity of 0.08 μg/mL.

Measures of body composition

At baseline, total fat mass was assessed in the Health ABC study by dual energy x-ray absorptiometry (Hologic QDR 4500A, software version 8.21, Hologic, Waltham, MA). Weight in kilograms was measured with a standard balance beam scale, and height in meters was measured with a Harpenden stadiometer (Holtain Ltd., Crosswell, U.K.).

Sociodemographic and lifestyle variables

Sociodemographic variables including age, gender, self-identified racial group and education, and lifestyle variables including smoking status, alcohol consumption, and physical activity were assessed at baseline of the Health ABC study. Lifetime pack-years of cigarette smoking were calculated by multiplying cigarette packs smoked per day by the number of years of smoking. Physical activity was evaluated by a standardized questionnaire specifically designed for the Health ABC study. This questionnaire was derived from the

leisure time physical activity questionnaire and included activities commonly performed by older adults (Taylor *et al*., 1978). The frequency, duration, and intensity of specific activities were determined, and approximate metabolic equivalent unit (MET) values assigned to each activity category to estimate weekly energy expenditure.

Genotyping

The Health ABC cohort was genotyped, using polymerase chain reaction restriction fragment length polymorphism analysis (PCR-RFLP), for the Pro12Ala polymorphism of the *PPAR-γ* gene by Beamer et al. (Health ABC, 2008). In the current study population, *PPAR-γ* Pro12Ala genotype frequencies were found to be in Hardy-Weinberg equilibrium.

Statistical analysis

Characteristics of men and women were examined by dietary pattern cluster, and each cluster was compared to the 'Healthy foods' cluster with Dunnett's test for continuous variables and chi-square test for categorical variables. Multiple regression models were constructed to compare mean measures of glucose metabolism and inflammation of each cluster to the 'Healthy foods' cluster, adjusted for possible confounding factors including gender, age, race, clinical site, education, physical activity, smoking status and total calorie intake. The interaction of dietary pattern with *PPAR-γ* genotype was tested, as were interactions of dietary pattern with gender and race. As they were not found to be significant, analyses were conducted in the study population as a whole. As BMI was considered a potential intermediate in a causal pathway between dietary patterns and insulin sensitivity and inflammation, it was not included as a covariate in the main analyses. However, BMI was added to a subsequent model to determine its effect on results. Statistical significance was set at $p \leq 0.05$, and analyses were performed using SAS (version 9.1; SAS Institute Inc., Cary, NC).

Results

Six clusters were identified: 1) 'Healthy foods' (n=319); 2) 'Breakfast cereal' (n=258); 3) 'Meat and alcohol' (n=31); 4) 'Sweets and desserts' (n=289); 5) 'Refined grains' (n=284); and 6) 'High-fat dairy products' (n=570). The 'Healthy foods' cluster had relatively higher intake of lowfat dairy products, fruit, whole grains, poultry, fish and vegetables, and lower consumption of red meat, added fats and high-calorie drinks (Table 1).

The 'Healthy foods' cluster had a significantly higher percent of women than all other clusters, as well as a higher percent of white participants, a higher level of education, and fewer pack-years of smoking (Table 2). With respect to diet, the 'Healthy foods' cluster had a significantly higher percent energy from protein, higher intake of fiber, higher Healthy Eating Index score, and lower percent energy from saturated fat than all other clusters. The 'Healthy foods' cluster also had a significantly higher percent energy from carbohydrate, lower percent energy from total fat, and lower dietary glycemic index and load than most other clusters.

The 'Healthy foods' cluster had significantly lower fasting insulin and HOMA-IR values than both the 'Breakfast cereal' cluster and the 'High-fat dairy products' cluster, after

adjusting for gender, age, race, clinical site, education, physical activity, smoking status and total calorie intake (Table 3). The ‘Healthy foods’ cluster also had a significantly lower fasting glucose level than the ‘High-fat dairy products’ cluster. No significant differences were found between the ‘Healthy foods’ and other clusters in 2-hour glucose. With respect to inflammatory markers, the ‘Healthy foods’ cluster had a significantly lower level of IL-6 than both the ‘Sweets and desserts’ cluster and the ‘High-fat dairy products’ cluster. No significant differences in CRP or TNF-α were seen between the ‘Healthy foods’ and other clusters. After further adjustment for BMI, the difference in fasting glucose between the ‘Healthy foods’ and ‘High-fat dairy products’ clusters was no longer significant, nor were the differences in fasting insulin and HOMA-IR between the ‘Healthy foods’ and ‘Breakfast cereal’ clusters. Other results were not substantially altered.

Discussion

In this study of older adults, dietary patterns were associated with specific indicators of insulin sensitivity and inflammation. Several previous studies also linked dietary patterns to insulin sensitivity. In a study of adults aged 50-69 years, a ‘prudent’ diet was related to higher insulin sensitivity (Villegas *et al*., 2004). Additionally, among women aged 40–60 years, a ‘healthy’ dietary pattern was inversely associated and a ‘Western’ pattern positively associated with insulin resistance (Esmaillzadeh *et al*., 2007b). Furthermore, among men aged 40-75 years, Fung *et al*. (2001) found an inverse association between a ‘prudent’ pattern and fasting insulin and a positive association between a ‘Western’ pattern and fasting insulin.

Previous research has also linked dietary patterns to markers of systemic inflammation. In a study of women aged 40-60 years, Esmaillzadeh *et al*. (2007a) showed an inverse association between a ‘healthy’ dietary pattern and plasma CRP, and a positive association between a ‘western’ pattern and plasma CRP and IL-6. Similarly, in a study of adults aged 45–84 years, Nettleton *et al*. (2006) found a positive association between a ‘fats and processed meats’ pattern and CRP and IL-6, an inverse association between a ‘whole grains and fruit’ pattern and CRP and IL-6, and an inverse association between a ‘vegetables and fish’ pattern and IL-6. Furthermore, in a study of women aged 43-69 years, a ‘prudent’ pattern was inversely associated with plasma CRP, while a ‘Western’ pattern was positively related to CRP and IL-6 (Lopez-Garcia *et al*., 2004). In a study of men aged 40-75 years, a “Western” pattern was also positively associated with CRP (Fung *et al*., 2001). Additionally, in a study of adults aged 50-74 years, a “healthy” dietary pattern was inversely associated with CRP (Nanri *et al*., 2008).

It is difficult to compare results of dietary pattern studies, as derived patterns are unique to each study population. However, dietary patterns associated with insulin resistance and inflammation have consistently included certain food groups. A dietary pattern high in whole grains, vegetables, fruit, poultry, fish and lowfat dairy products, and low in refined grains, red meat, sweetened beverages, added fats, sweets, and high-fat dairy products, has been associated with higher insulin sensitivity. With respect to inflammation, a dietary pattern high in vegetables, fruit, whole grains, fish, poultry and legumes, and low in refined grains, red and processed meat, sweets, sweetened beverages, and fried potatoes, has been

linked to lower systemic inflammation. These dietary patterns may contribute to lower metabolic risk because they are high in specific protective nutrients, some perhaps not yet identified, but the current study was not intended to investigate the effects of individual nutrients.

While this study showed significant differences among clusters in IL-6, but not in CRP or TNF-α, all inflammatory markers displayed similar patterns. This would be expected, as inflammation involves a cascade in which tissue injury stimulates cells to produce pro-inflammatory cytokines, which in turn stimulate hepatocytes to produce acute-phase proteins. TNF-α and IL-6 thereby promote increased production of CRP by the liver. One unexpected finding was that the 'Meat and alcohol' cluster did not exhibit significantly higher metabolic risk than the 'Healthy foods' cluster. Because the 'Meat and alcohol' cluster had a substantially smaller sample size than the other clusters, however, these findings may not be highly meaningful.

The mechanisms to explain associations of diet with inflammation and insulin resistance have not been fully elucidated, though several theories have been suggested. Excess body fat has been linked to both insulin resistance and a state of chronic low-grade systemic inflammation, and inflammation may contribute to insulin resistance. Adipose tissue expresses cytokines such as TNF-α and IL-6, which may induce insulin resistance by impairing insulin signaling (Qatanani and Lazar, 2007). When the current analyses were adjusted for BMI, differences in several indicators of insulin sensitivity among clusters were no longer significant. This could support an intermediate role of excess body fat in a causal pathway between diet and insulin sensitivity. Due to the cross-sectional nature of this study, however, it is not possible to determine if a variable such as BMI is in a causal pathway, or if it is a confounding variable.

This study did not show an interaction between dietary pattern and *PPAR-γ* genotype in relation to insulin sensitivity or inflammation. Several studies have associated the common Pro12Ala polymorphism in the *PPAR-γ* gene with insulin sensitivity and inflammation, and some have suggested that its effects may depend on the diet (Heikkinen *et al*., 2009; Soriguer *et al*., 2006). It is possible that the dietary patterns in this study did not differ sufficiently in the main dietary ligands of PPAR-γ, which may include derivatives of monounsaturated and polyunsaturated fatty acids, to show an interaction with *PPAR-γ* genotype. In addition, some studies have indicated that effects of the *PPAR-γ* Pro12Ala genotype may vary according to BMI, gender, and other genetic polymorphisms, and these potential influences on the interaction between diet and *PPAR-γ* genotype were not investigated in this study (Razquin *et al*., 2009).

Strengths of this study include its focus on adults aged 70 and older, a little-studied population, and simultaneous examination of multiple measures of insulin sensitivity and systemic inflammation. In addition, analyses were controlled for numerous potential confounders, and a genetic interaction was considered. A limitation of this study is that the cross-sectional design does not allow inference of a causal relationship between diet and metabolic risk factors. Furthermore, this study population consisted of relatively well-functioning older adults at presumably lower metabolic risk, and it is possible that

associations between diet and insulin sensitivity and inflammation would be stronger in a study population of less healthy older adults.

In conclusion, the current and previous studies suggest that a 'healthy' dietary pattern, high in whole grains, vegetables, fruit, poultry, and fish, and low in refined grains, red and processed meat, high-fat dairy products, sweets and desserts, and sweetened beverages, is associated with both greater insulin sensitivity and a lower level of systemic inflammation when compared to other dietary patterns. Because indicators of insulin sensitivity and systemic inflammation have been linked to risk of multiple chronic diseases, diets that promote higher insulin sensitivity and lower systemic inflammation should be encouraged in older adults. Dietary interventions to lower metabolic risk in older adults could be targeted to groups according to their current dietary patterns.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Table 1

Percent energy contribution from selected food groups for the 6 dietary pattern clusters

Food group	Percent energy contribution[1]											
	Healthy foods (n=319)		Breakfast cereal (n= 258)		Meat and alcohol (n=31)		Sweets and desserts (n=289)		Refined grains (n=284)		High-fat dairy products (n=570)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Processed meat	1.7	1.8	2.6	2.7	**4.2**	3.0	2.7	2.6	3.7	3.0	3.6	3.1
Meat	2.8	2.6	3.3	2.9	**4.6**	3.5	3.7	2.9	3.7	3.1	3.7	2.9
Fish and other seafood	**2.6**	2.4	1.8	2.4	1.2	1.9	1.3	1.5	1.5	2.1	1.6	2.9
Poultry (not fried)	**3.0**	3.7	2.0	2.0	1.6	1.8	2.0	2.3	1.9	2.4	2.1	2.6
Fried poultry	0.4	1.0	0.7	1.4	**2.1**	3.5	0.8	1.4	1.2	2.0	1.2	2.3
Lowfat dairy products	**9.1**	6.0	2.2	3.6	1.1	2.4	1.7	3.0	1.2	2.4	0.7	1.6
Higher-fat dairy products	3.1	2.4	7.0	4.6	6.6	4.6	6.4	4.7	5.4	4.0	**9.8**	6.9
Beer	0.2	0.9	0.3	1.4	**17.1**	8.3	0.4	1.5	0.3	1.4	0.4	1.1
Liquor	0.7	2.5	0.6	1.9	**3.3**	9.4	0.5	1.9	0.6	1.8	0.9	2.6
Fruit	**7.6**	5.0	4.6	3.7	2.8	2.0	3.6	2.9	3.9	3.5	4.4	3.5
Dark green vegetables	**0.4**	0.5	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.4	0.3	0.3
Dark yellow vegetables	**1.1**	1.3	0.7	0.7	0.4	0.5	0.7	0.9	0.8	1.1	0.8	1.0
Other vegetables	**1.3**	1.2	1.2	1.5	0.9	0.8	1.0	1.0	1.3	1.2	1.2	1.2
Whole grains	**5.5**	5.1	2.8	3.1	1.7	2.0	2.2	2.6	1.8	3.1	3.6	4.0
Cold breakfast cereal – fiber/bran	3.0	3.6	**3.7**	5.0	0.6	1.3	1.6	2.6	1.0	1.9	1.7	2.5
Other cold breakfast cereal	7.2	4.4	**18.7**	6.3	3.7	4.3	5.5	4.3	4.3	4.3	4.8	3.6
Refined grains	9.9	5.0	8.8	5.0	10.0	5.1	9.9	5.3	**24.5**	6.9	10.5	4.2
Rice, pasta and mixed dishes	**3.9**	3.7	2.9	2.4	3.5	2.9	3.2	2.7	3.1	2.9	3.6	3.5
Snacks	1.5	3.3	1.4	2.6	1.5	2.7	2.3	4.1	1.6	2.7	**2.6**	4.8
Nuts	3.8	4.3	2.4	3.8	2.3	3.5	3.2	3.7	3.1	3.8	**4.3**	5.9
High-calorie drinks	0.9	2.1	2.0	3.4	1.4	2.1	2.4	3.8	3.1	4.5	**3.5**	5.0
Mayonnaise and salad dressing	3.3	3.0	3.5	3.1	3.7	3.1	3.1	2.9	3.1	2.8	**4.5**	2.9
Sweets and desserts	6.6	4.8	7.0	5.0	5.2	3.7	**24.4**	8.3	7.7	5.4	6.7	4.2
Miscellaneous fats	3.6	3.4	3.9	3.3	5.3	3.7	4.1	3.5	5.2	4.0	**5.5**	4.4

[1] Clusters with the highest percent energy contributions from each food group are in bold, and clusters with the lowest percent energy contributions from each food group are underlined.

Table 2

Characteristics of the study population by dietary pattern cluster[1]

	Healthy foods (n=319)		Breakfast cereal (n=258)		Meat and alcohol (n=31)		Sweets and desserts (n=289)		Refined grains (n=284)		High-fat dairy products (n=570)	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Characteristics												
Gender (% men)	36.7		53.9[2]		83.9[2]		47.4[2]		51.1[2]		45.8[2]	
Age (years)[3]	75.0	0.2	75.4	0.2	74.1	0.5	75.1	0.2	75.1	0.2	75.0	0.1
Race (% White)	83.4		75.6[2]		64.5[2]		75.8[2]		53.9[2]		55.3[2]	
Education (% completed high school)[4]	90.6		83.3[2]		71.0[2]		84.8[2]		61.6[2]		77.7[2]	
Smoking (lifetime pack-years)[4]	12.5	1.2	18.4[2]	1.7	42.5[2]	7.7	20.3[2]	1.8	18.8[2]	1.5	17.9[2]	1.1
Alcohol (% any consumption)[4]	61.8		55.4		100.0[2]		56.1		46.1[2]		52.3[2]	
Physical activity (kcal/week)[4]	1431	111	1155	103	1640	674	1012[2]	90	953[2]	102	981[2]	70
PPAR-γ Pro12Ala genotype (n (%))[5]												
Pro/Pro	260 (82.5)		203 (80.2)		27 (87.1)		233 (82.6)		247 (88.9)[2]		467 (84.0)	
Ala/Pro and Ala/Ala	55 (17.5)		50 (19.8)		4 (12.9)		49 (17.4)		31 (11.2)[2]		89 (16.0)	
Body composition												
BMI (kg/m^2)[4]	26.3	0.3	27.1	0.3	27.1	0.9	26.2	0.2	26.8	0.3	27.4[2]	0.2
Total body fat (%)[4]	35.7	0.4	35.1	0.5	30.7[2]	1.1	34.9	0.4	34.3	0.5	35.5	0.3
Dietary factors[3]												
Total calorie intake (kcal)	1688	29	1722	35	2013[2]	116	2051[2]	40	1853[2]	40	1853[2]	27
% kcal from carbohydrate	57.4	0.4	59.3[2]	0.5	43.3[2]	1.3	52.5[2]	0.4	53.3[2]	0.4	50.4[2]	0.3
% kcal from protein	16.2	0.2	14.0[2]	0.2	13.0[2]	0.5	12.9[2]	0.1	13.8[2]	0.1	14.4[2]	0.1
% kcal from fat	27.7	0.3	28.1	0.4	31.9[2]	1.1	36.0[2]	0.3	34.0[2]	0.4	36.3[2]	0.3
% kcal from saturated fat	7.5	0.1	8.2[2]	0.1	9.4[2]	0.4	10.6[2]	0.1	9.4[2]	0.1	10.7[2]	0.1
Total dietary fiber (g)	20.3	0.4	17.3[2]	0.4	15.1[2]	1.2	17.1[2]	0.4	16.4[2]	0.4	17.0[2]	0.3
Dietary glycemic index (glucose scale)	54.4	0.2	59.6[2]	0.2	50.2[2]	1.0	55.8[2]	0.2	58.8[2]	0.2	55.2[2]	0.2
Dietary glycemic load (glucose scale)	120.6	2.3	141.8[2]	3.2	103.2	7.3	140.1[2]	2.8	135.5[2]	3.3	119.0	1.9

	Healthy foods (n=319)		Breakfast cereal (n= 258)		Meat and alcohol (n=31)		Sweets and desserts (n=289)		Refined grains (n=284)		High-fat dairy products (n=570)	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Healthy Eating Index score	80.5	0.4	72.7[2]	0.6	66.5[2]	2.0	64.2[2]	0.7	67.6[2]	0.7	67.6[2]	0.5

[1] Means and SE, unless otherwise specified.

[2] Significantly different from the 'Healthy foods' cluster, $P \leq 0.05$ (Dunnett's test for continuous variables and chi-square test for categorical variables).

[3] Values from year 2 of the Health ABC study.

[4] Values from baseline of the Health ABC study.

[5] Genotype information not available for 36 participants.

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Table 3

Multivariate-adjusted means of biochemical variables by dietary pattern cluster[1]

	Healthy foods (n=319)		Breakfast cereal (n=258)		Meat and alcohol (n=31)		Sweets and desserts (n=289)		Refined grains (n=284)		High-fat dairy products (n=570)	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Fasting glucose (mg/dL)												
Model 1[2]	91.7	0.5	93.0	0.6	95.3	1.8	91.6	0.5	91.7	0.6	93.4[3]	0.4
Model 2[4]	91.7	0.5	92.9	0.6	94.7	1.8	91.3	0.6	92.0	0.6	93.5[3]	0.4
Model 3[5]	91.9	0.5	92.7	0.6	94.6	1.7	91.5	0.5	92.1	0.5	93.3	0.4
Fasting insulin (μU/mL)												
Model 1[2]	6.1	0.2	7.0[3]	0.2	5.9	0.6	6.6	0.2	6.8	0.2	7.0[3]	0.2
Model 2[4]	6.2	0.2	6.9[3]	0.2	5.7	0.6	6.5	0.2	6.7	0.2	7.0[3]	0.2
Model 3[5]	6.3	0.2	6.8	0.2	5.7	0.5	6.7	0.2	6.8	0.2	6.9[3]	0.1
2-hour glucose (mg/dL)												
Model 1[2]	118.4	2.1	122.6	2.4	119.4	7.0	119.4	2.3	117.3	2.2	120.7	1.6
Model 2[4]	118.7	2.2	122.4	2.5	118.3	6.9	119.0	2.3	117.6	2.3	120.7	1.6
Model 3[5]	119.1	2.2	121.8	2.4	118.1	6.8	119.5	2.3	117.9	2.3	120.3	1.6
HOMA-IR												
Model 1[2]	1.4	0.0	1.6[3]	0.1	1.4	0.2	1.5	0.1	1.5	0.1	1.6[3]	0.0
Model 2[4]	1.4	0.0	1.6[3]	0.1	1.3	0.1	1.5	0.1	1.5	0.1	1.6[3]	0.0
Model 3[5]	1.4	0.0	1.5	0.1	1.3	0.1	1.5	0.0	1.6	0.0	1.6[3]	0.0
C-reactive protein (μg/mL)												
Model 1[2]	1.6	0.1	1.8	0.1	1.5	0.2	1.8	0.1	1.8	0.1	1.8	0.1
Model 2[4]	1.7	0.1	1.8	0.1	1.4	0.2	1.9	0.1	1.7	0.1	1.8	0.1
Model 3[5]	1.7	0.1	1.7	0.1	1.4	0.2	1.9	0.1	1.7	0.1	1.7	0.1
Interleukin-6 (pg/mL)												
Model 1[2]	1.6	0.1	1.7	0.1	2.2	0.3	1.9[3]	0.1	1.8[3]	0.1	1.9[3]	0.1
Model 2[4]	1.7	0.1	1.7	0.1	2.0	0.2	1.9[3]	0.1	1.8	0.1	1.9[3]	0.0

	Healthy foods (n=319)		Breakfast cereal (n=258)		Meat and alcohol (n=31)		Sweets and desserts (n=289)		Refined grains (n=284)		High-fat dairy products (n=570)	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Model 3[5]	1.7	0.1	1.7	0.1	2.0	0.2	1.9[3]	0.1	1.8	0.1	1.9[3]	0.0
Tumor necrosis factor- α (pg/mL)												
Model 1[2]	2.9	0.1	3.0	0.1	2.9	0.2	3.2	0.1	3.2[3]	0.1	3.2[3]	0.1
Model 2[4]	2.9	0.1	2.9	0.1	2.7	0.2	3.1	0.1	3.2	0.1	3.2	0.1
Model 3[5]	3.0	0.1	2.9	0.1	2.7	0.2	3.1	0.1	3.2	0.1	3.1	0.1

[1] Geometric means and SE.

[2] Adjusted for gender, age and race.

[3] Significantly different from the 'Healthy foods' cluster, $P \leq 0.05$ (Dunnett's test).

[4] Adjusted for gender, age, race, clinical site, education, physical activity, smoking status, and total calorie intake.

[5] Adjusted for gender, age, race, clinical site, education, physical activity, smoking status, total calorie intake, and BMI.